RESISTANCE-COUPLED
AUDIO AMPLIFIERS
A
Preleminary Treatise

# A Vintage Radio MONOGRAPH

by

D. H. MOORE

*The Editorial Group, Ltd...*

P.O. BOX 521 • PALO ALTO, CALIFORNIA

*"They copied all they could follow,*
*But they couldn't copy my mind.*
*And I left 'em sweating and stealing*
*A year and a half behind."*
—KIPLING

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PLEASE NOTE

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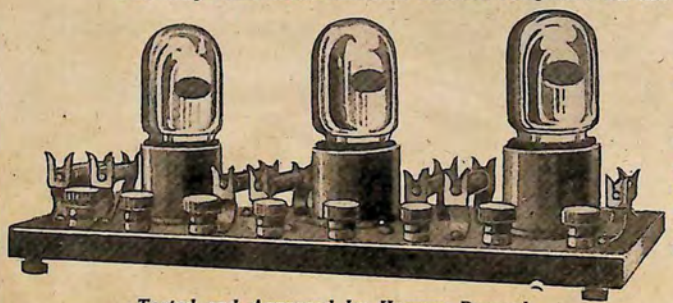

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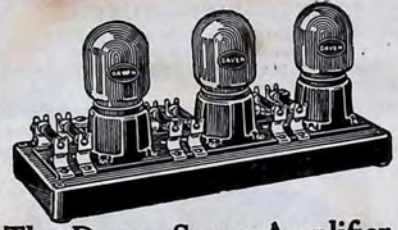

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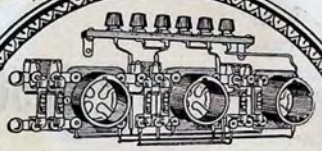

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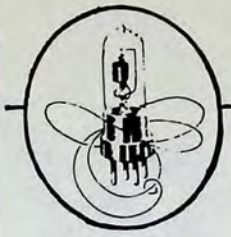

# Beyond Rider!...!!

In the early days of Radio, whenever a "new" circuit or kit or set was advertised, there was usually an extensive listing of firms whose parts had been used in the circuit or set being touted...a sort of tacit co-op in advertising. The priciple remains valid, and with that in mind, we append a general listing of an impressive amount of well-organised and researched data on a host of early marques you're not likely to find in the usual references, such as Rider's and Beitmann; but indicative of the treasure-trove of constructional and technical data to be found in VINTAGE RADIO IDENTIFICATION SKETCH-BOOKS of D.H.MOORE. Why not expand your knowledge along with your enjoyment of the hobby with sole-source information, in many instances? Send for your free flyer & others' endorsements today!

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# RESISTANCE-COUPLED AMPLIFIERS

## A Preliminary Treatise

In the beginning there was an obsession for reception, any kind of reception, intelligable or not. As the art advanced there was a pre-occupation with "tone", and from flimsy PM speakers evolved the massive and frequently ornate dynamic and electro-dynamic spakers. It was inevitable, of course, that another synthetic controversy arose.

It was actually the longest-running editorial controversy, the debate over the virtues and demerits of the four types of AF amplification - *i.e.*, transformer-coupled, impedance-coupled, push-pull, and resistance-coupled. The controversy ranged from Zeh Bouck and the very articulate Henney, to Lynch and Priesley. Nothing was advanced, of course, and the controversy died a natural death under the avalanche of rapid new discoveries or applications. But such controversies, sophomoric as most of them were, did have one positive effect upon an army of Radio media readers - they were confronted with the necessity for thinking, of crystallising their own thoughts.

I have constructed and experimented with about 50 or so of all types of the early AF circuits, and found that Henney was correct when he editorialised that the impedance-type was the most inferior & Harris was correct when he wrote that the transformer-coupled type is the easiest, and the cheapest to produce, and that manufacturers were going to push that type - which they have done ever since.

While some of the advert claims by such firms as Thor and Daven and Na-Ald were obviously puffered, it is easily demonstrable I find that the resistance-coupled AF amplifiers can produce the purest tones, and with the proper power tubes and hi-mu tubes, will produce volume enough to fill a hall. Such circuits were clean in design, are practically fool-proof, and will work with any circuit.

The following free-hand sketches offer a handful of better

R-C circuits. The parts and components required can usually be found in your "junk box". So, on some odd Thursday when it's raining, have a go at constructing one or two.

* * *

Simply stated, R-C AF amplification is an early system which allows intensifying current variations through the magnifying action of the various tubes of the day. The signal from one tube is passed along to the next tube through the functioning of a high resistance included in the plate circuit of the preceding tube.

With any incoming signal, the plate current of a first tube necessarily varies in amplitude, which causes changes across the potential existing at the terminals of the following resistor. This varying potential is applied to the grid of the next tube through the mandatory coupling condenser (called an "isolating" condenser in the early days). This condenser isolates the high positive potential applied to a first tube. The fourth resistor is a conventional grid-leak, preventing choking by an accumulation of excessive changes in the grid.

One of the virtues of an R-C amplifier is that once you have decided on the circuit you prefer, the values of the components remain constant. This is not true of other types, especially push-pull.

The ordinary transformer-coupled and impedance-coupled types may be considered allied, in that the latter has two windings in which the coefficient of the coupling and the turns-ratio are near unity. The later models of Alden's "Truphonic" amplifier is a good example. Impedance-types act as an auto-former, the same windings acting as PRI. and a part of the SEC, at the same time.

In the transformer-coupled type, the maximum amplification a stage at a time is equal to the amplification constant of the preceding tube, multiplied by the turns-ratio of the transformer. The voltage of the SEC bears the same ratio to the input, or PRI, voltage as the number of turns in the SEC bears to the turns of the PRI. In other words:

$$\frac{v1}{v2} = \frac{n1}{n2}$$

where:

v1 & v2 = PRI & SEC voltage.
n1 & n2 = PRI & SEC Turns

This step-up voltage occurs only under certain theoretical conditions, which are never attained in actual practice. However, the maximum voltage attainable in a transformer-coupled type is:

$$K = \mu \frac{n2}{n1}$$

where: K = total voltage amplification
$\mu$ = Voltage amplifying constant of tube.

All early transformers were noted for their distortion, as they could not produce the same amplification at all frequencies. The result of this was the development of the three other types of audio amplifying systems. The R-C type remained the most popular, not only with set-constructors but several commercial manufacurers as well.

The relationship between input and output of the R-C types is practically linear. What distortion may occur is due to stress imposed by unfavourable tube characteristics. While the amplification a stage at a time is not so great as that of the transformer-type, the results per dollar spent was and is the ultimate standard in terms of efficiency, and here the R-C types rank foremost.

The early push-pull amplifiers actually increased output a very small amount when compared with the transformer-coupled circuits but the P-P type was capable of killing distortion, using a considerably higher plate voltage without over-loading the tubes. The C-bias, sometimes of a very high order, was mandatory.

* * *

Three stages of R-C amplification are quite sufficient for most purposes, giving amplification generally greater than a 2-stage transformer-coupled type. Two stages inputted from an *efficient* tuner of the reflex type will drive a speaker easily. More than a 3-stage R-C amplifier is not recommended with reflex and super-het sets. Four stages have proved to be the practical limit, and a switching device for putting out the fourth tube should always be provided, as it's not needed except for very weak signals. Further, if you do use a 4-stage system, do not use the 01A - use 16A, 12A, 71A. With the 16A a coupling resistor of 100K is suggested.

R-C can be added to a transformer-coupled stage using only the first AF transformer, and shunting the second. Using both results in distortion. Also, when utilizing a stage of transformer-coupled AF only two stages of R-C are needed.

As for RF amplification, the R-C type is not too efficient from 200 to 500 meters. This is because the coupling resistor is virtually shunted by the plate to filament capacity of the preceding and

driving tube. In effect, a by-pass about the resistor through which a radio frequency detours. R-C amplification, however, is quite effective on waves above 2000 meters, which makes it quite satisfactory for use as an IF amplifier in super-hets of the day.

Variable resistances are not necessary, although you will find one such amid the following sketches. The values are all uncritical, you will note. Any values between 50K and 150K gives almost unchanged amplification; 100K is usually the most efficient. When used with reflex input or a transformer-coupled stage, 50K is recommended for the first R-C stage.

While the 01A was generally used, other tubes will perform quite satisfactorily, and include such as 99, WD-11, D2, D3, Meyers, and "N". The Meyers tube was an excellent tube for R-C systems: not a lot are around today, it seems.

Because plate inductances and their accompanying feed-back are eliminated, the R-C system is probably the most stable of all amplifying circuits or arrangements. But it should be stressed that only *absolutely good* tubes should be used in all stages. Weak or orphan tubes are a wastage, and will almost always result in acoustic howl. Howling has also been known to occur in 4-stage systems when the last tube is cut in or out. When this happens, the last coupling resistors should be increased to the highest value giving the best results. The grid-leak can also be fine-tuned for greater stability.

R-C amplification functions with the effect of a negative bias being applied to audio frequencies - *i.e.*, the varying positive charge on the coupling side of the isolating condenser induces similar negative fluctuations on the grid side. This causes the plate curremtn to "modulate down", to decrease when the amplifier is operating so no extra bias is necessary.

Plate voltage of at least 100V should always be used. One may go up to twice the maximum potential recommended by the tube manufacturer, as the actual applied voltage is greatly reduced by coupling resistors which are in series with the plate supply. I have found that I could impress 140VDC on the plate of an 01A successfully.

When inputting from a DET tube, plate voltage of the DET should be doubled or tripled. DET plate potential should be increased until the tube detects most efficiently, or, as in the case of regenerative sets, until the set regenerates and oscillates in a conventional manner. Because of the increase in voltage phone jacks may not and should not be inserted into the DET circuit. It is a good custom to insert a 5K to 50K resistor in series with speaker leads, to lower plate current, due to the low resistance of early phones.

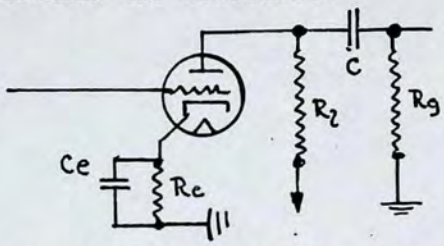
Any R-C aplifier circuitry is coupled to any type or kind

of receiver in exactly the same manner, regardless of any diversity of circuitry.

* * *

TECHNICAL & THEORETICAL DISCUSSION:

R-C amplifiers using Triodes have a frequency characteristic that is determined by the capacitance values across the plate & grid reistance & coupling condenser together the cathode by-pass. The following sketch details the constants:




Condenser C is in series with $R_g$. Reactance $X_o$ varies with frequency, being largest at low frequencies, attenuating most of the lower frequencies, unless the condenser has a resistance that is small in comparison with $R_g$.

The plate cathode capacitance is across $R_1$ and the *effective* grid-filament capacitance is across $R_g$. These two capacitances bypass higher frequencies, the degree of attenuation being dependent upon the size of the resistors and tube capacitances. For a fixed capacitance of a tube, the lower the resistance values the better the frequency response.

The *effective* grid-cathode capacitance of a tube is *not* equal to the static capacity, measured when the tube is disconnected via the plate supply. The grid-plate capacity is reflected back and capacity is added across the grid-leak. The total effective capacity, then:

$$C_{eff} = C_{ge} + C_{gr}\ (1+A)$$

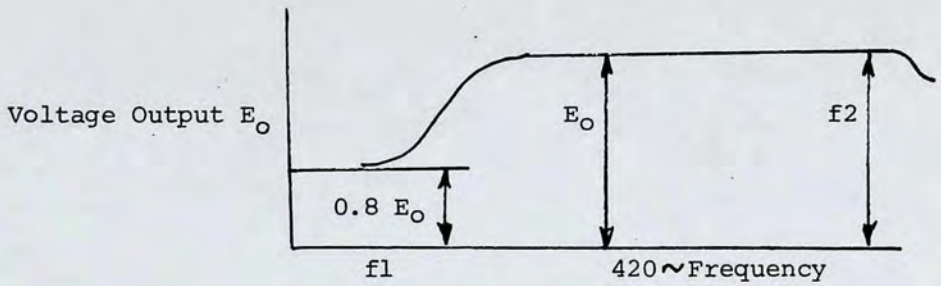
where:
$A$ = gain in tube.
$C_{ge}$ = grid-cathode capacity.
$C_{gr}$ = grid-plate capacity.

The effective capacity may become large when hi-mu tubes of the early Daven type are used. When several hi-mu tubes are employed a risk arises of high frequencies being attenuated too much.

The bias resistor and by-pass condenser also influence frequency characteristics. There will be a voltage drop across then that is applied again to the grid in reverse phase. Thus, when impedance of

the combination rises, the reversed feed-back increases and output becomes less. The lower the resistance of the by-pass condenser, better is the low frequency response.

FREQUENCY CHARACTERISTICS OF A SINGLE-STAGE R-C TRIODE AMPLIFIER:




At the low end f1 = 100 cycles as 0.8 of output.
f2 = high frequency cut-off point.

When similar stages are used in cascade, voltage output at f1 will be .08 times the output at 420 cycles.

* * *

When using three or more stages, decoupling filters are required. This is not necessary for one and two stages.

The employment of self-bias has the advantage of automatic compensation for variations in the plate voltage, or slight difference in tube characteristics. Thus, self-bias is preferred to fixed bias. A variation of 10% in resistor or condenser values will have little effect on the performance of an R-C system.

Constants not previously defined:

C = blocking condenser - 1 MFD
$C_c$ = cathode by-pass - 1 MFD
$R_g$ = grid resistor in Megohms
$R_c$ = cathode resistance in Ohms
$R_1$ = plate resistance in Megohms
$E_o$ = Voltage output (peak Voltage)
$E_{bb}$ = plate supply voltage in volts

When a mathematical analysis is made of the R-C amplifier a large coupling capacitor is found to be unnecessary. It is the combination of coupling condenser and grid-leak that determines the quality of the output. If the condenser is large, the grid-leak can be small & vice versa. The same frequency characteristics will obtain either way.

If a 100K resistance is used in the plate circuit, the following combinations may be used to obtain a practically flat response curve down to 50 cycles:

| GRID-LEAK: | CPLNG. CONDENSERS: |
|---|---|
| 0.2 Megohms | .06 MFD |
| 0.5 Megohms | .025 MFD |
| 1.0 Megohms | .012 MFD |
| 2.0 Megohms | .006 MFD |

The greatest problem that seems to be attached to R-C amplifiers is due to the occasional blocking of tubes. This blocking only occurs, however, when the tube is over-loaded. This makes it essential that the proper C-bias be used on the grids of all tubes. It is quite easy to calculate the grid-bias if the circuit characteristics as well as the amplification constants of the tube is known. Such calculations would show, for example, that for a 20-mu tube the C-bias for a first hi-mu tube should not be more than one volt, and that four volts would be about right for the grid of the second tube.

Such values permit a grid being at 40 volts peak value on a 71A power tube in the last stage, for example.

* * *
* *
*

DAVEN's FIRST R-C AUDIO AMPLIFIER KIT ADVERT, 1925

## The Daven Radio Type 3-C Amplifier Kit

as illustrated, contains all the parts necessary to build a three stage *resistance coupled amplifier*. It is packed in a neat compartment box with full directions for assembly and operation with any detector and tuner.

Price Complete $13.50

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Only an amplifier that can reproduce a woman's voice with the sweetness and color of reality—the mellow richness of the contralto, the piercing beauty of the coloratura soprano—is worthy of being called "IDEAL." This is the acid test of amplifiers. Almost all amplifying systems fail before it, and only the *resistance coupled amplifier* passes the test consistently, economically and invariably.

## The Daven Radio Resistance Coupled Amplifiers

bring forth a new quality and beauty from every receiver, the most lowly or the most pretentious—a purity of tone that rarely passes the first tube. To the laymen, the *resistance coupled amplifier* is a revelation, to the virtuoso it is the realization of that subtle perfection that he alone appreciates!

*Read our booklet, "Resistors—Their Application to Radio Reception" By Zeh Bouck. Price 15 cents.*

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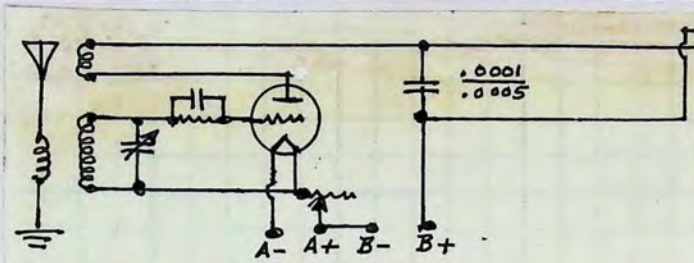
While there is, or was some controversy over whether or not DAVEN was the first to bring out a commercially successful R-C amplifier, there was no controversy as to whether or not it was the most popular among home constructors. The original offering was a kit, containing dual resistor mounts and the .006 mfd condensers; the Bakelite moulded base with tube sockets followed; and when the unit caught-on, the base was offered with nickel-plated tube socket skirts. While there was a rash of R-C amplifiers in the mid-Twenties, that offered by MONFORD was the only real competition to the DAVEN unit.

Resistance coupling was one of the oldest known methods of amplification, and was commonly used by amateurs with the earliest vacuum tubes, but becayse those early tubes had a low amplification factor, R-C was not considered to be very efficient. The advent of what were called Hi-Mu tubes, pioneered by DAVEN, changed all that. Where the 01A had an amplification factor of 6.5, DAVEN's Mu-20 had an amplification factor of 20. However, the Hi-Mu tubes were not "general application" tubes, and could not be used, being specifically designed for R-C and Impedance-Coupled AF amplifiers. The Hi-Mu 6, however, was a straight-forward power tube and could be used in conventional circuits.

The R-C amplifier can be installed in any set, following the DET, regardless of the number of tubes: simply remove the audio transformers, AF tube sockets and attendent wiring, and connect the R-C unit. R-C amplification offers twice the volume and a clarity of tone not to be gotten with general purpose tubes. As noted on the following page, the use of a C-battery is mandatory, although no rheostat or FIL resistance is required when used with a 6V A-battery. C-bias is as follows:

| Characteristic: | MU-20 | MU-6 |
|---|---|---|
| FIL Voltage | 5.5/6V | 5.5/6V |
| FIL Current | .25A | .5A |
| Plate Volt. | 90/180 | 90/180 |
| Plate Current | 1.1mA* | 12/15mA** |
| Plate Imp. | 40K | 3K |
| Amp. Constant | 20* | 5/6 |
| Mutual Conduct. | 500mo. | 2K mo. |
| Base | UX | UX |

* = 60V on plate, 0V grid, negative FIL, no plate resistance.
** = 135V on plate, 10.5V C-, grid to (-) FIL string.

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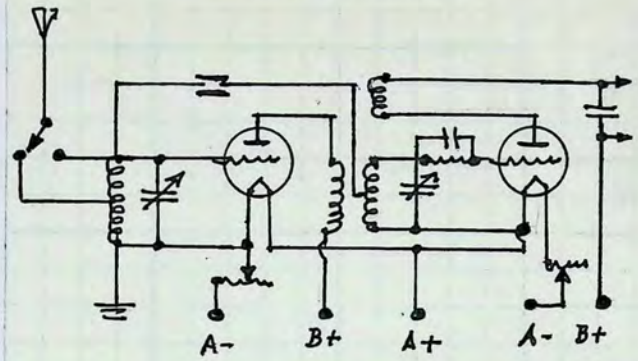


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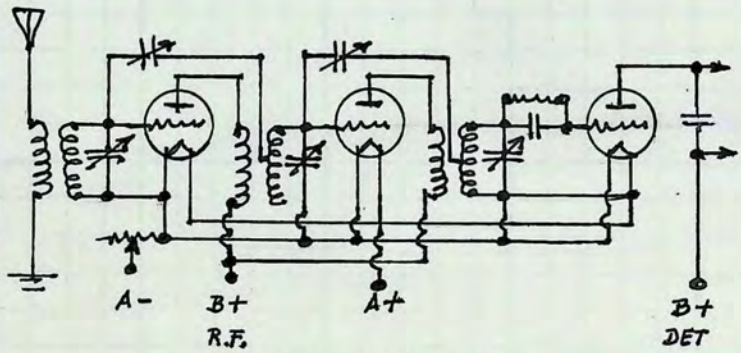


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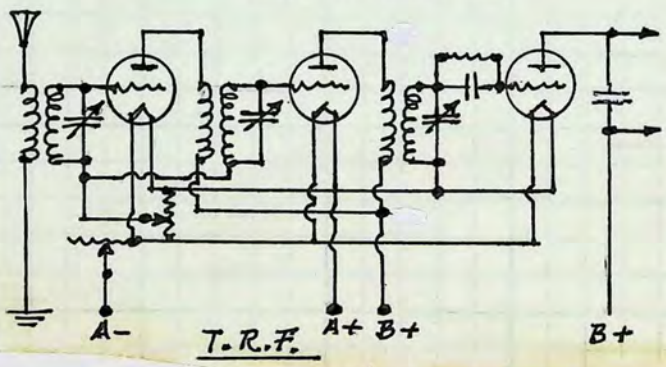
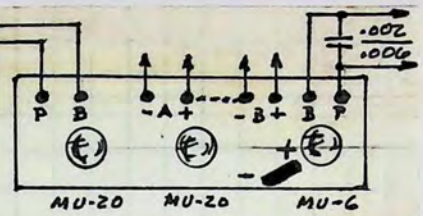



DAVEN R-C UNIT

NOTE: Jumper shown @ 3rd tube should be removed & a C-battery installed, noting polarity. With 90 to 110 VDC on the Pl, use 4.5 to 6V: w/ 135V, use 7.5 to 9VDC.

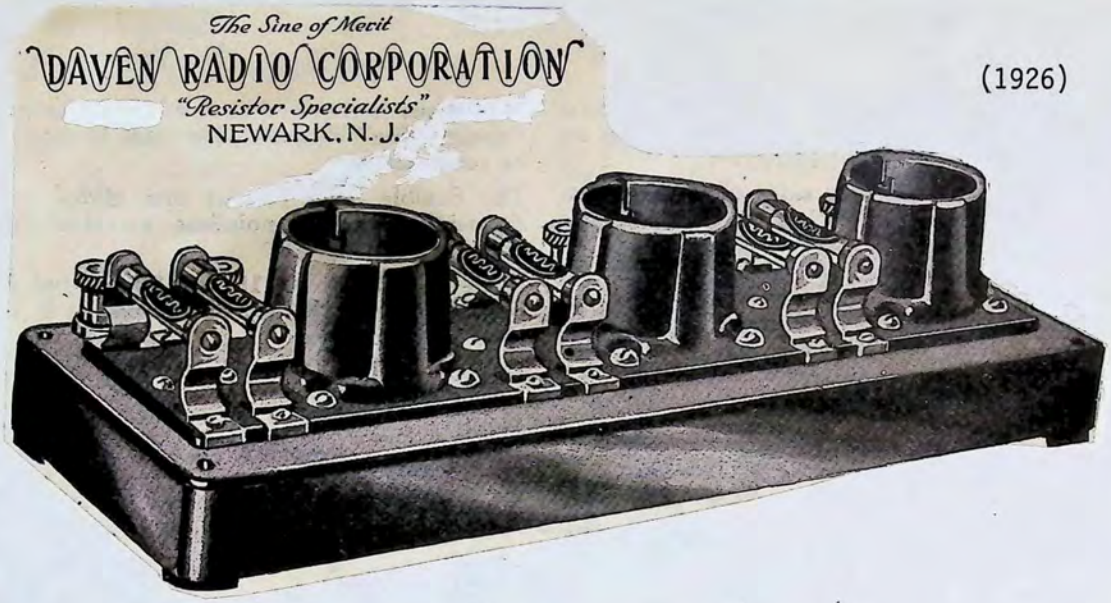
Connexions to the DAVEN R-C Unit is the same for ALL types of output circuits.

Output by-pass determined by best tone @ speaker or phones.

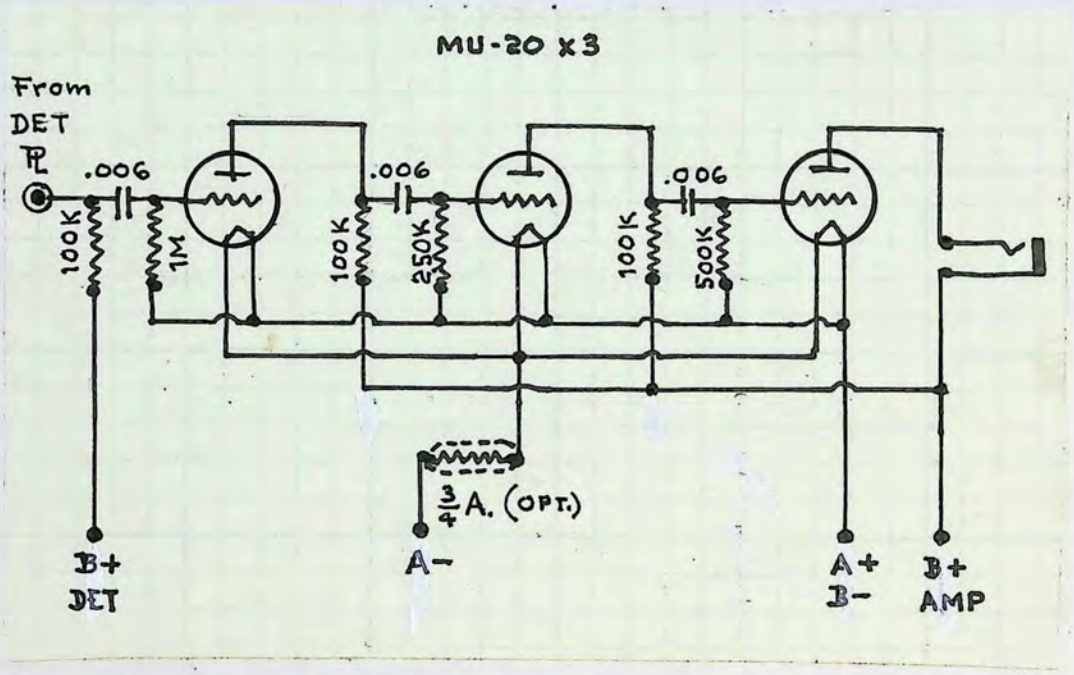
CAUTION

If your set has B- & A- joined, do not connect B- to B-terminal @ set. Connect B- to B-post on DAVEN R-C Unit.

(DAVEN Lit.)



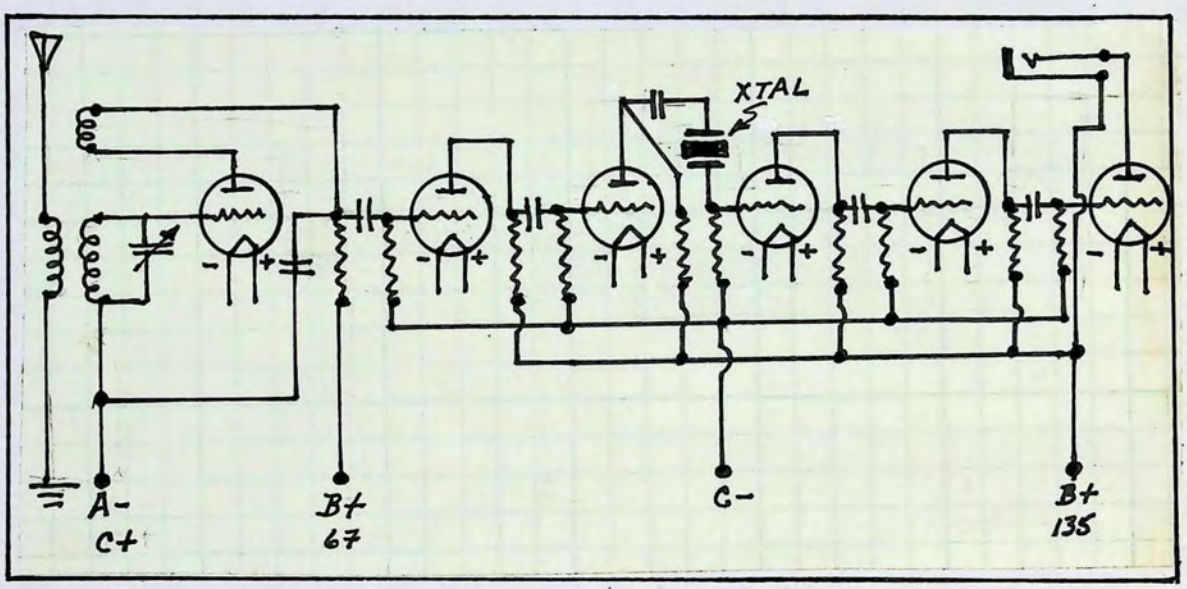

(1926)



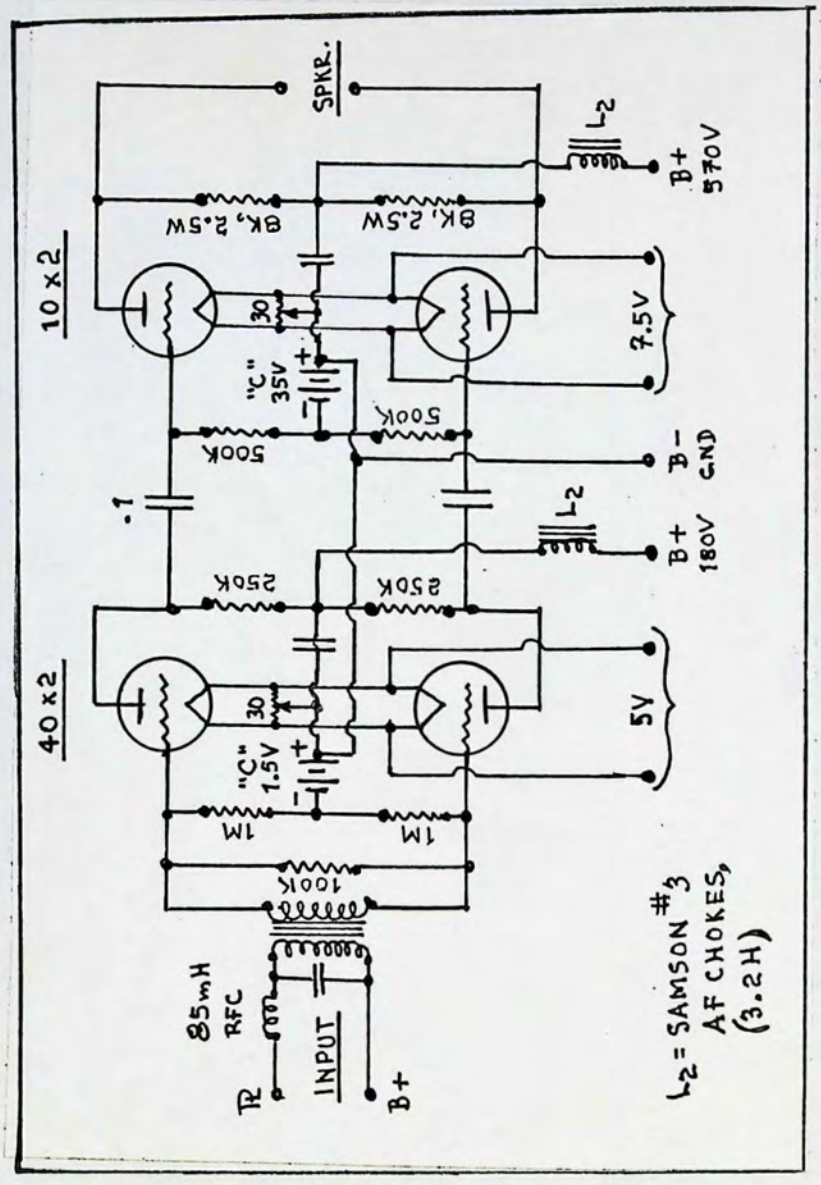

The DAVEN R-C Audio Amplifier may be considered as a-typical of the several marques that followed, such as Welty, General Radio, De-Jur, Sterling, Monford, Kelford, etc. Values of the resistors and the capacitors were not too critical, as my own experiments hav e demonstrated.

## R-C RF WITH CRYSTAL DETECTOR

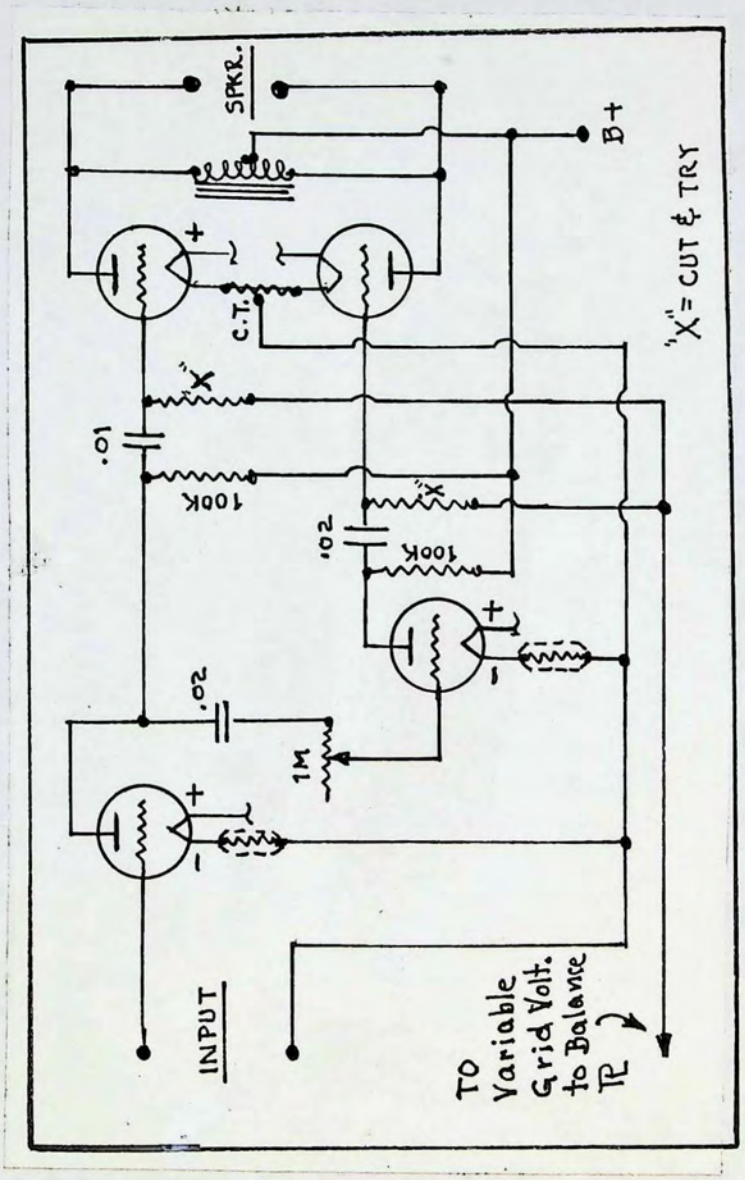
Resistance-Coupling of RF stages was never very popular, nor was it very effective, other than allowing a spurious claim of something new. The sketch below is of a 1926 circuit, incorporating R-C. All values were conventional for the time, and thus are not shown. The circuitry is primarily of academic interest, and it is not recommended as something you should have a go at. It would be a waste of time and materials, on the one hand; and you'd be disappointed in the results.



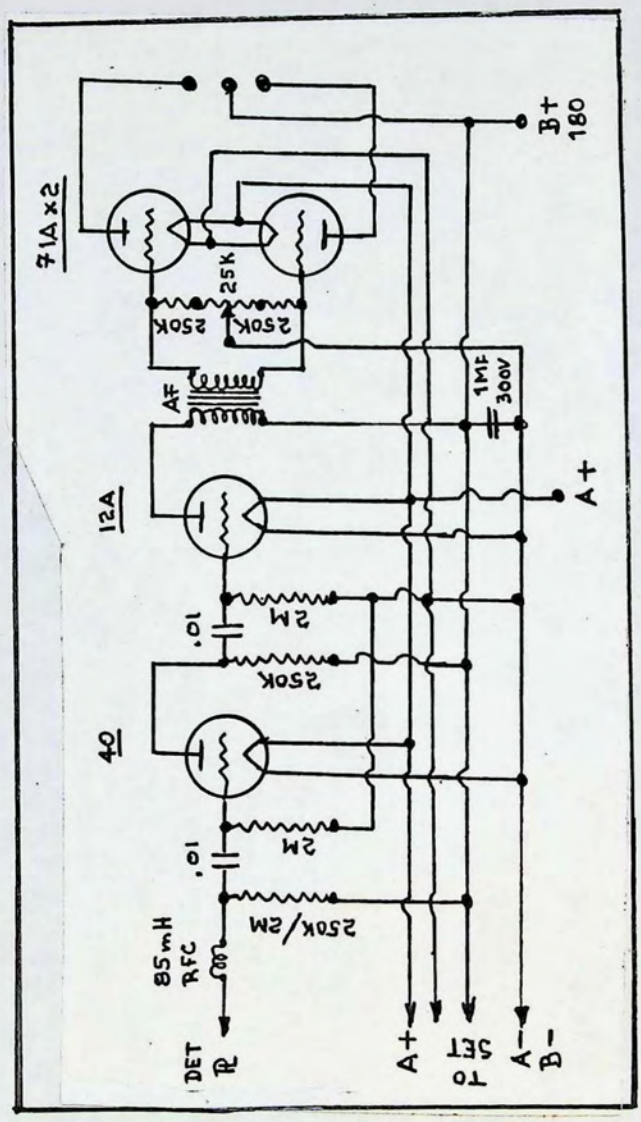
PUSH-PULL R-C AMPLIFIERS #1



PUSH-PULL R-C AMPLIFIERS #2

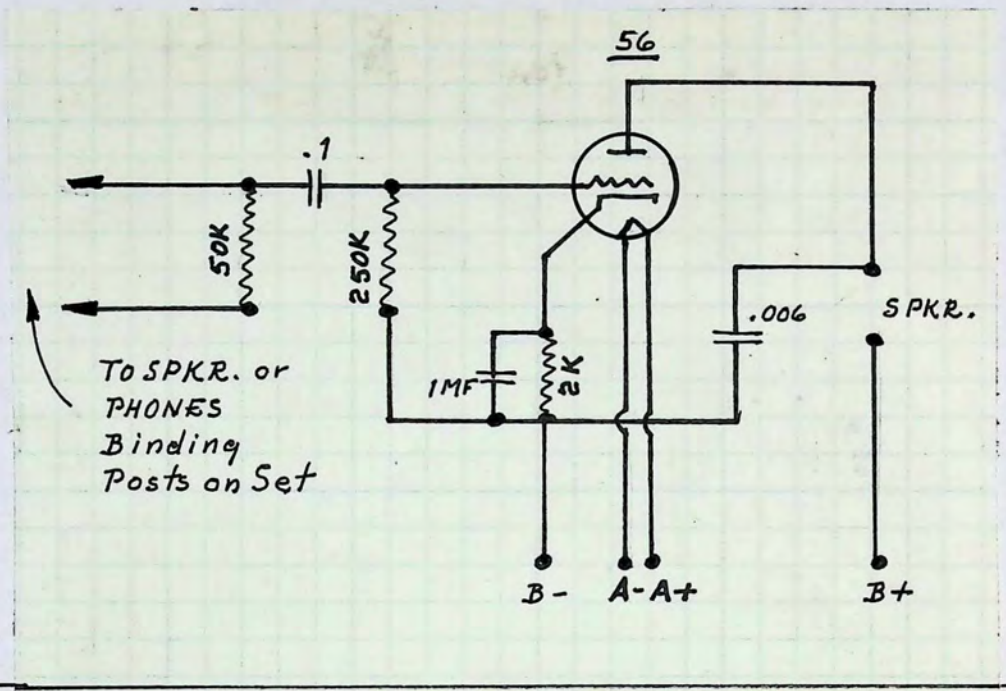


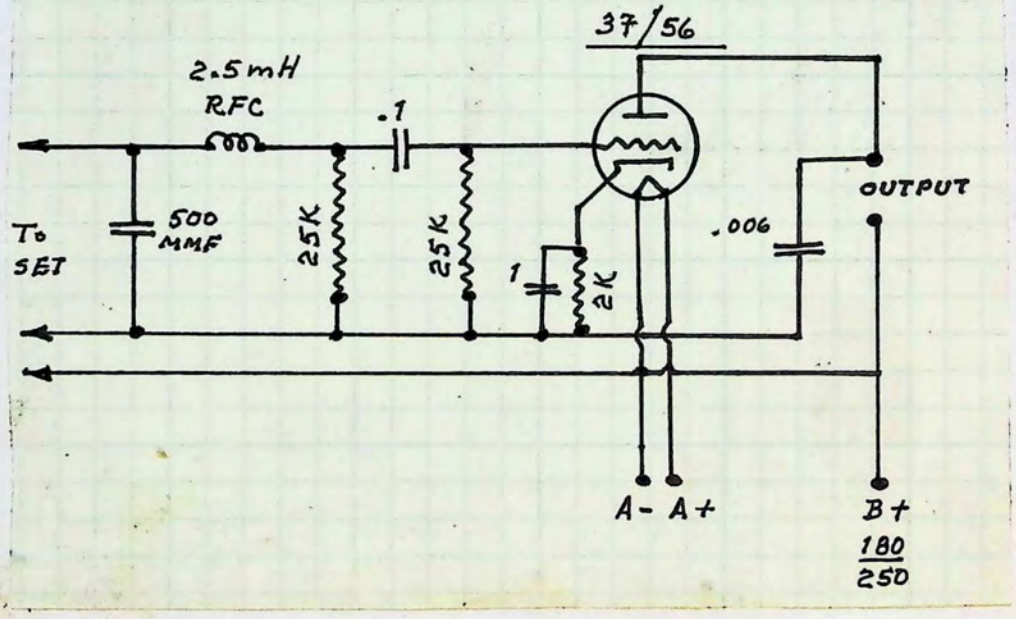
PUSH-PULL R-C AMPLIFIERS #3



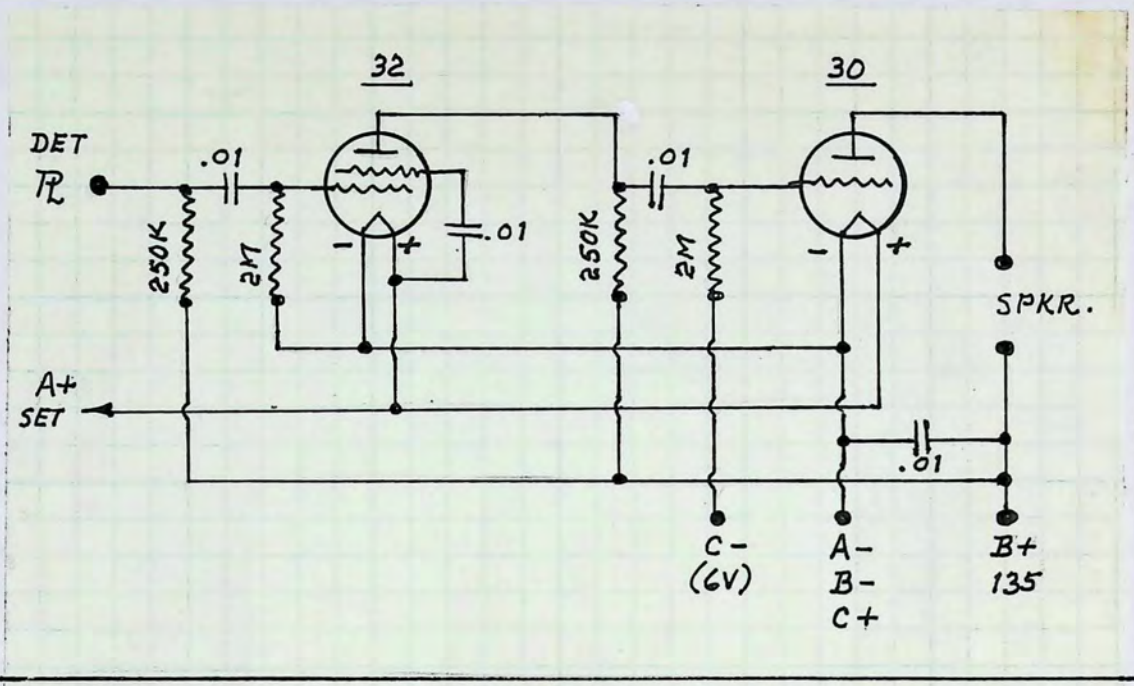

(Designed by Frank Henderson, 1927.)

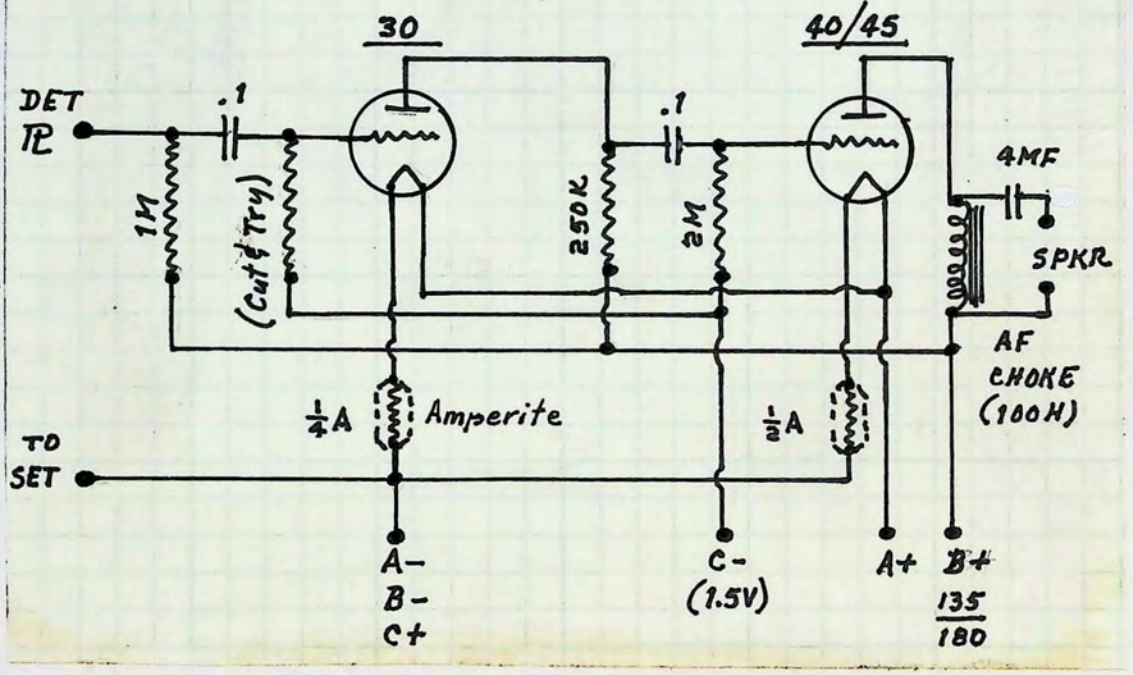
TYPICAL ONE TUBE R-C AMPLIFIERS, 1929



TYPICAL TWO TUBE R-C AMPLIFIERS #1



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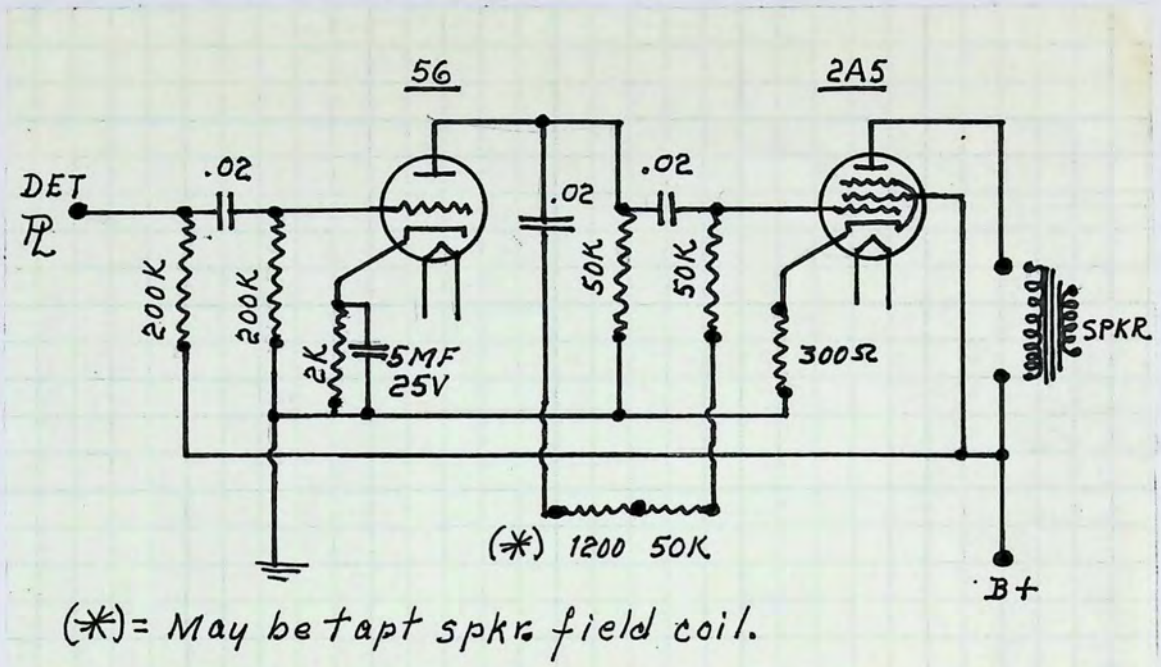
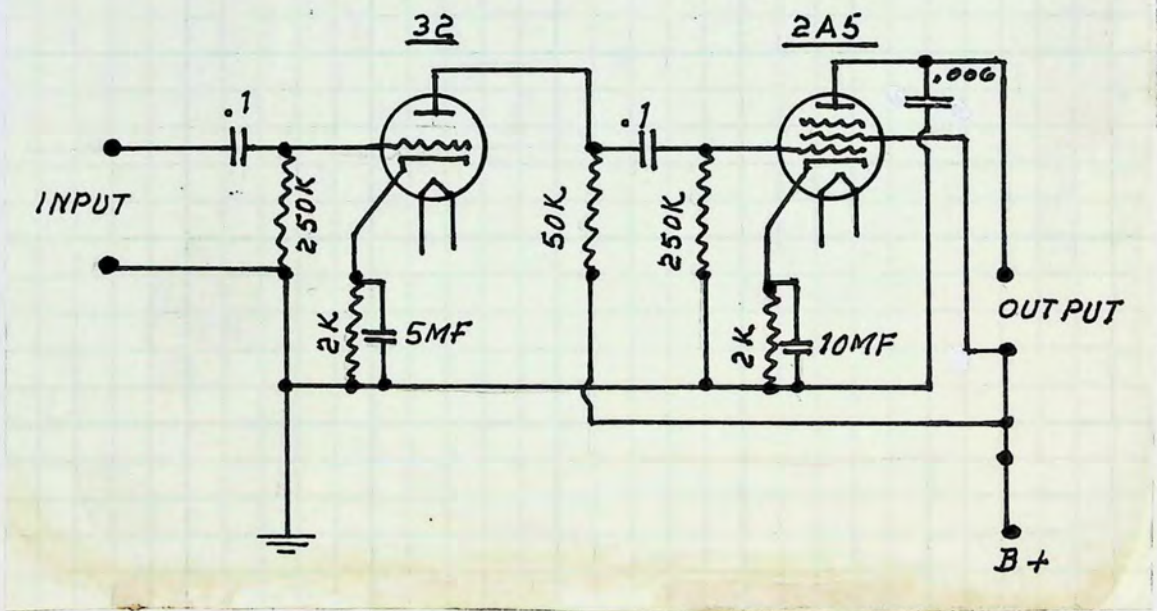
TYPICAL TWO TUBE R-C AMPLIFIERS #2

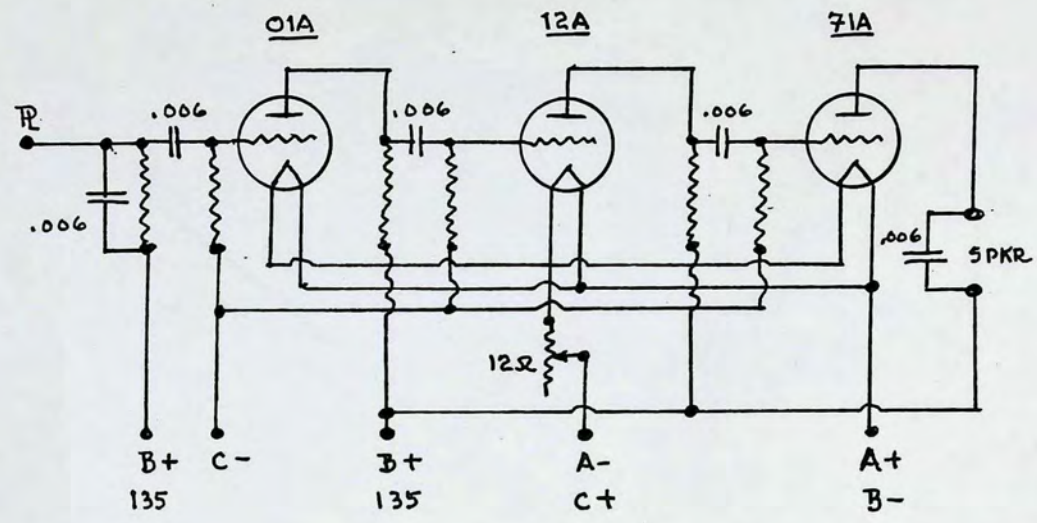


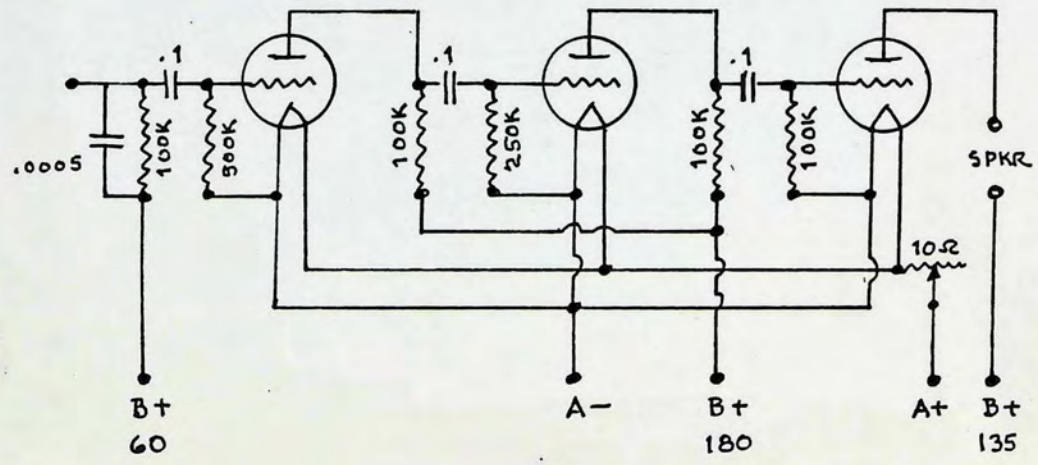

(*) = May be tapt spkr. field coil.



TYPICAL THREE TUBE R-C AMPLIFIERS #1

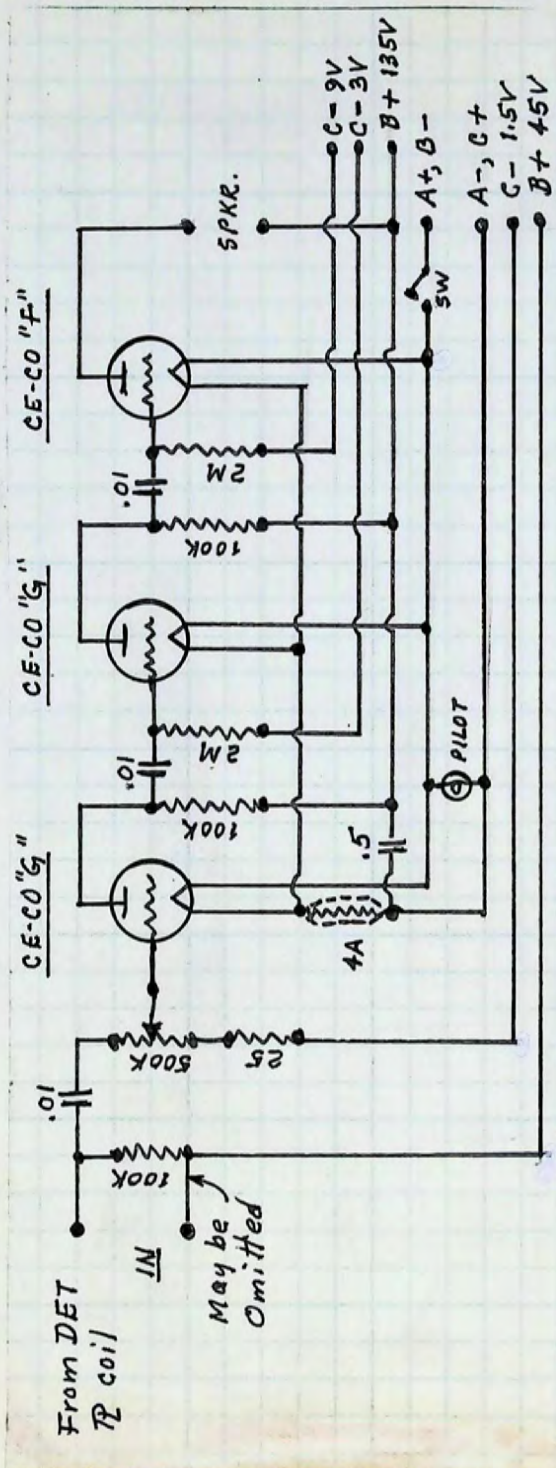
(ALDEN)



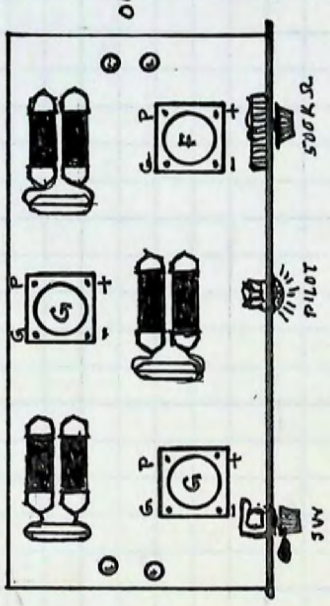




("A" STRING MAY BE TIED INTO "A" CIRCUIT OF SET.)

"DIAMOND-OF-THE-AIR" R-C AMPLIFIER
(1927)

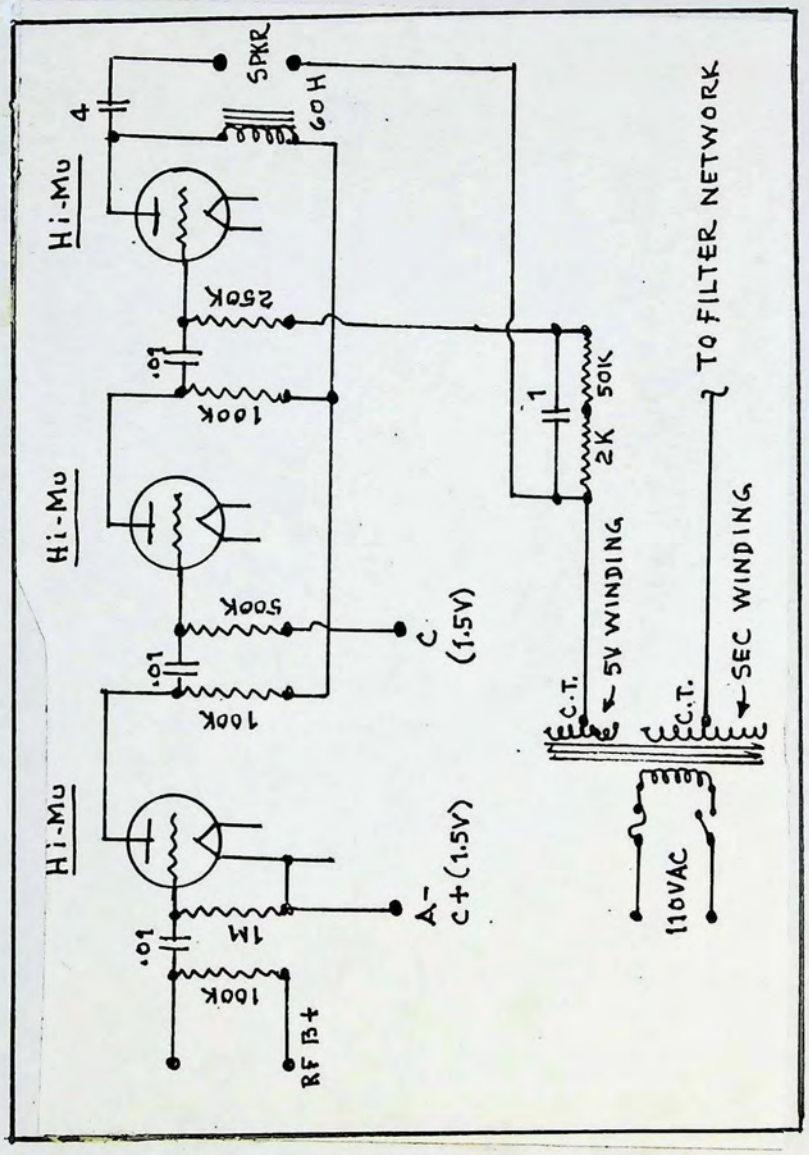



NOTE:
Ce-Co tubes did make a difference.

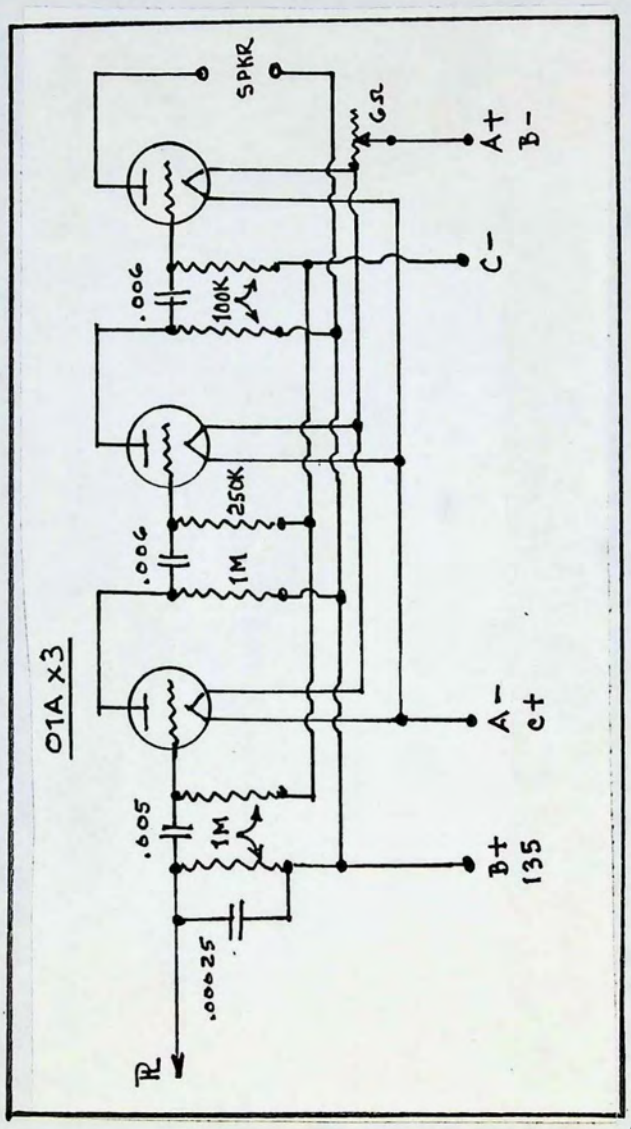



Baseboard = 8½" x 5⅛" x 3/16" (Bakelite).

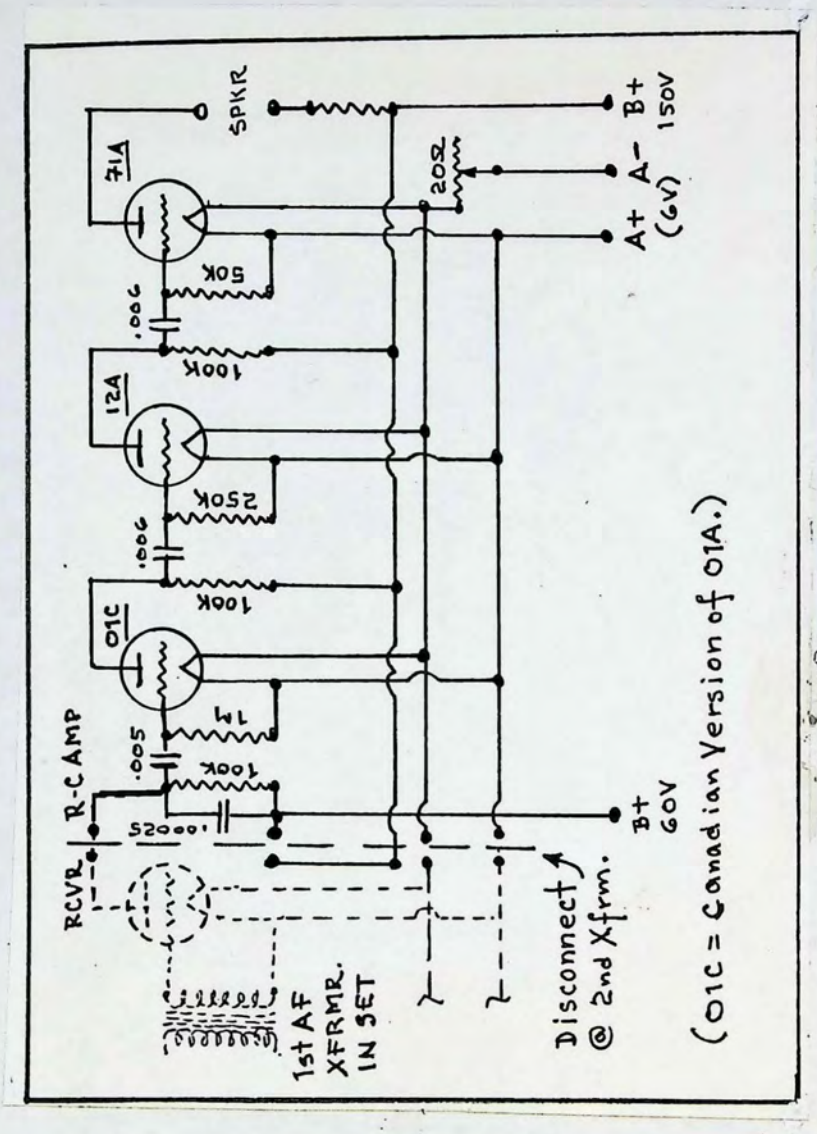
TYPICAL THREE TUBE R-C AMPLIFIERS #3
(DONGAN)



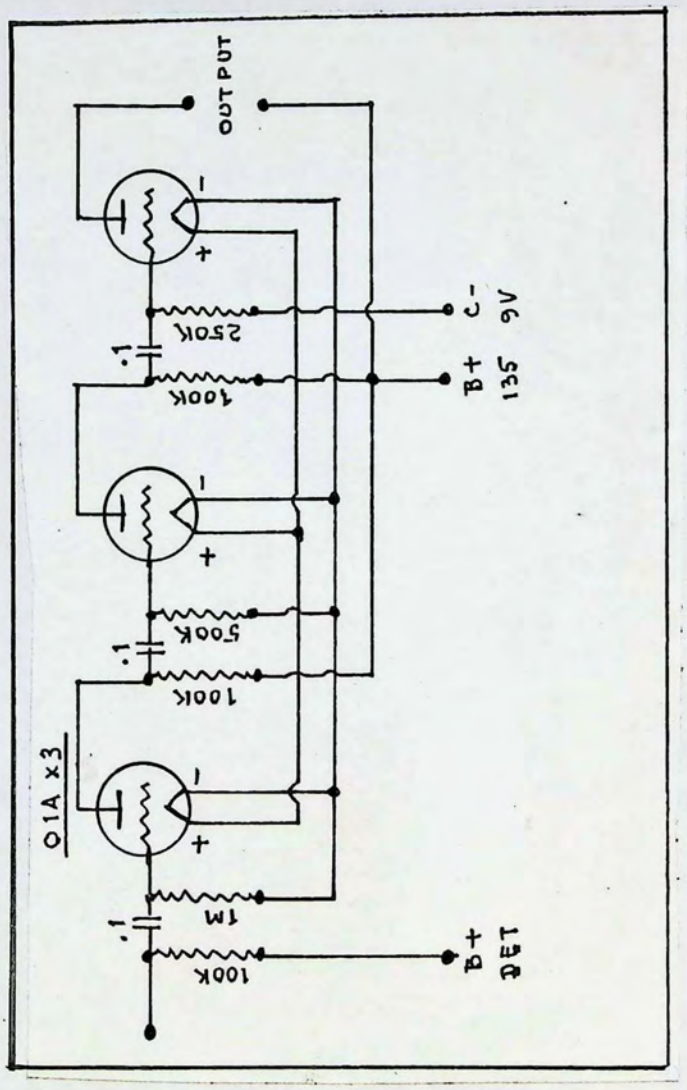
TYPICAL THREE TUBE R-C AMPLIFIERS #4
(BOUCK)



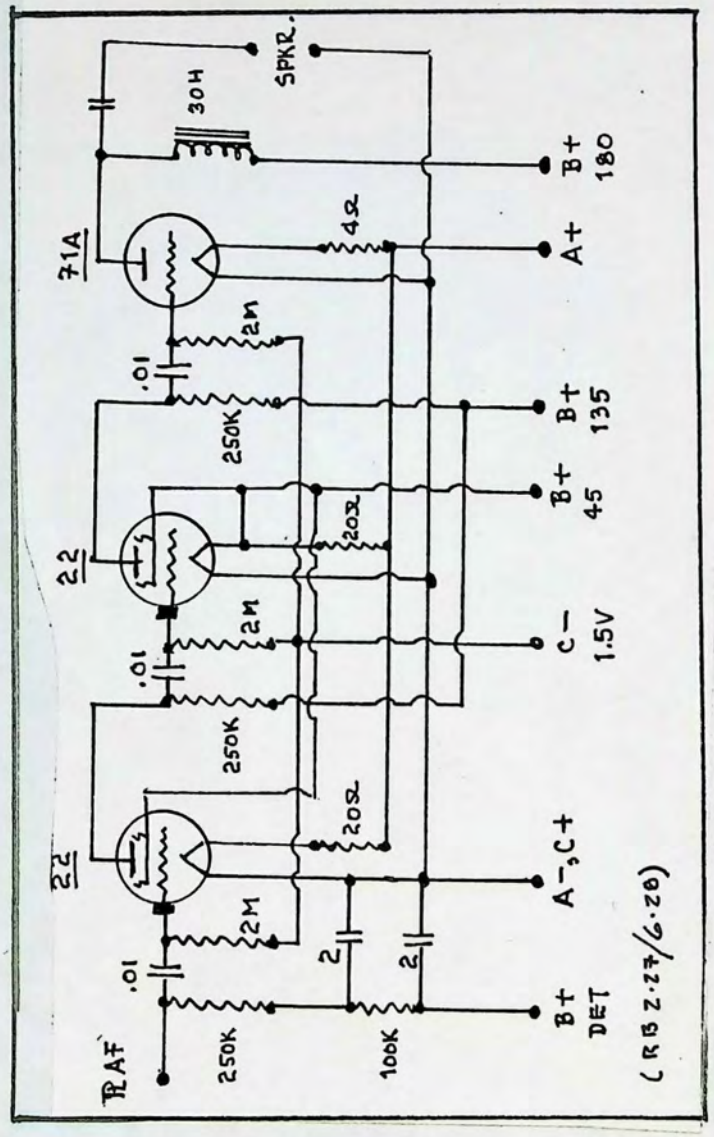
TYPICAL THREE TUBE R-C AMPLIFIERS #5
(CANADIAN)



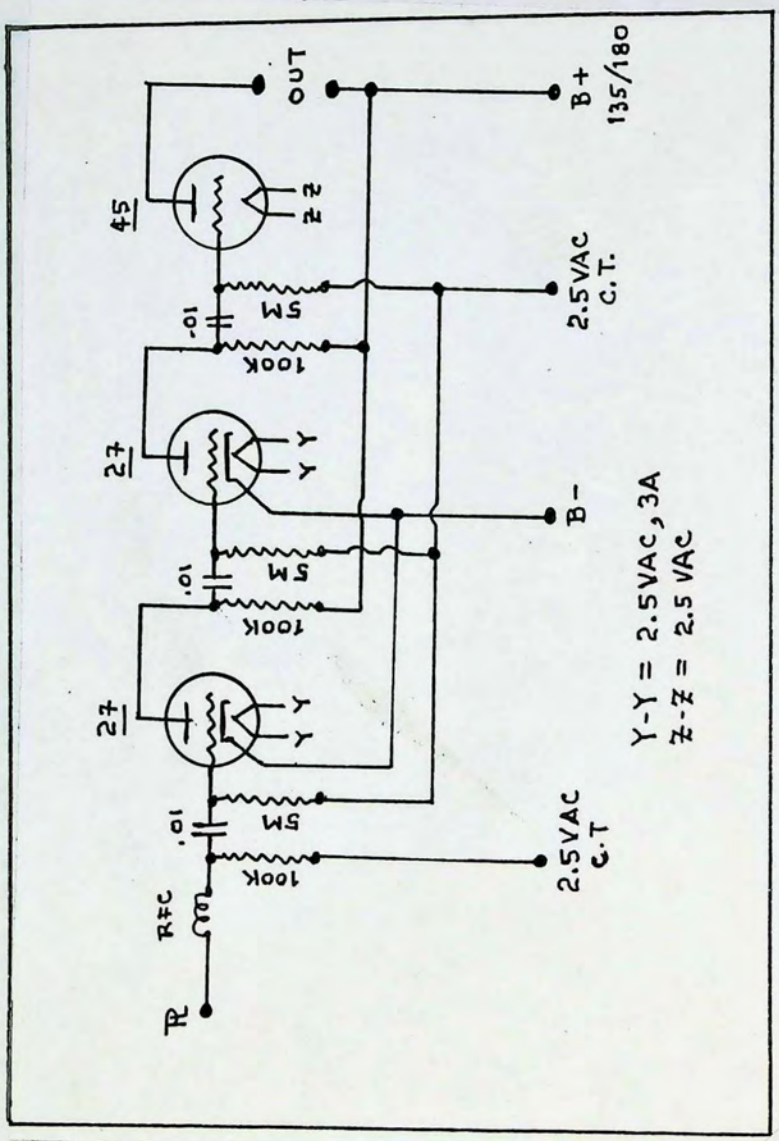
TYPICAL THREE TUBE R-C AMPLIFIERS #6
(NEELEY)



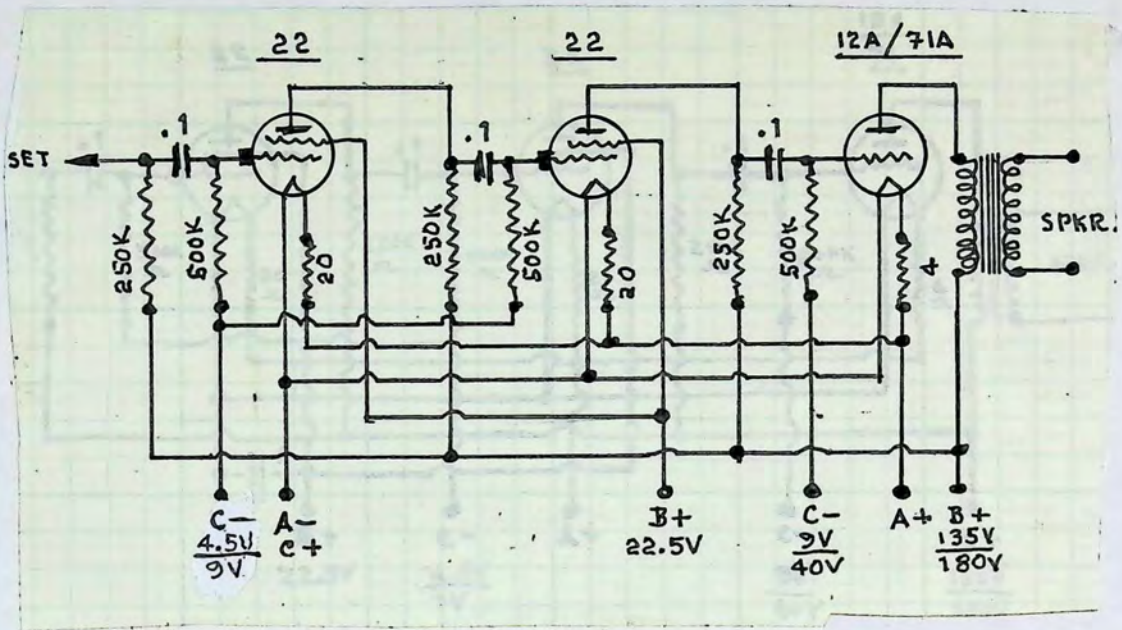
R-C AMPLIFIER WITH 22 TUBES



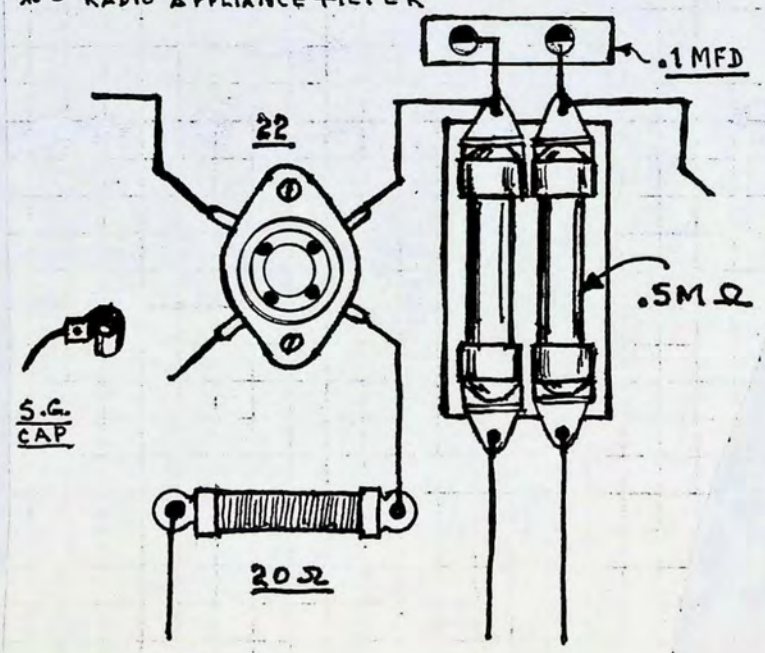
R-C AMPLIFIER WITH AC TUBES



R-C AMPLIFIER WITH SCREEN-GRID TUBES



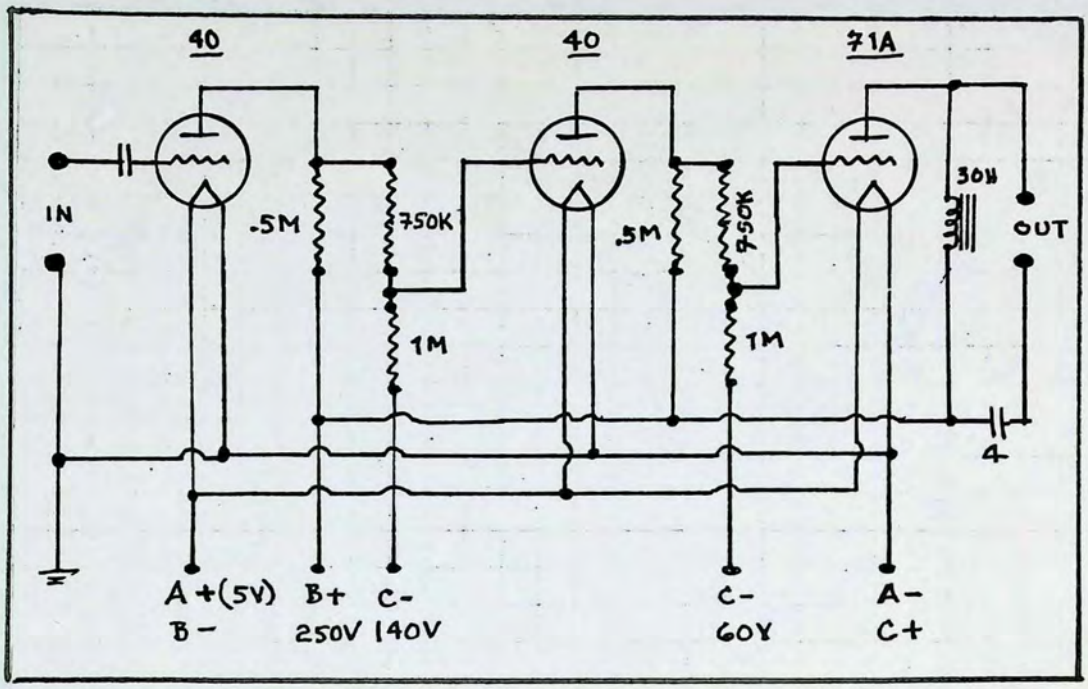

* = RADIO APPLIANCE FILTER




TYPICAL CONFIGURATION

(RN 4-30)

I.R.C. RESISTANCE-COUPLED AMPLIFIER, 1928



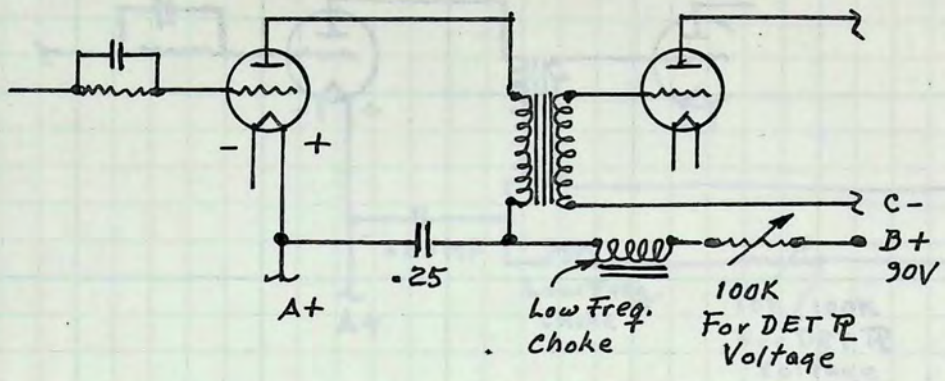

NOTES:

1. All batteries should be in series.
2. Plate and grid voltages are critical.
3. To adjust, insert a mAmeter in the plate circuits and adjust C-bias until meter shows rated current for the tube.
4. If using a B-eliminator, sufficient by-pass condensers should be placed across taps to prevent conductive coupling. (*)
5. Over-all gain is approximately the same as the usual R-C amplifier, but the frequency characteristic is flat over a longer range.

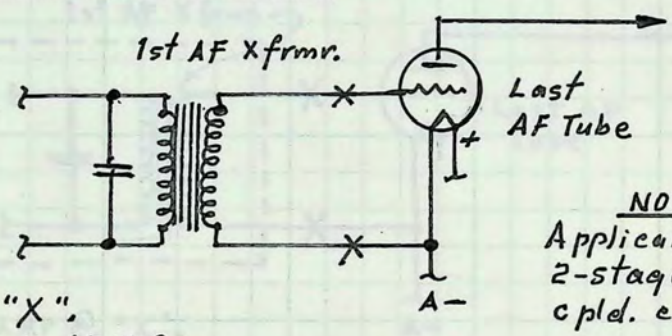
(*) = This is not necessarily true.

R-C AMPLIFICATION NOTATIONS

IMPROVING XFRMR. COUPLING:



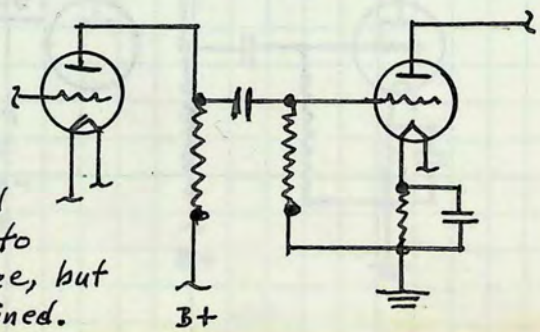

R-C COUPLING TO XFRMR.:




Couple @ "X", Shunt 2nd AF Xfrmr.

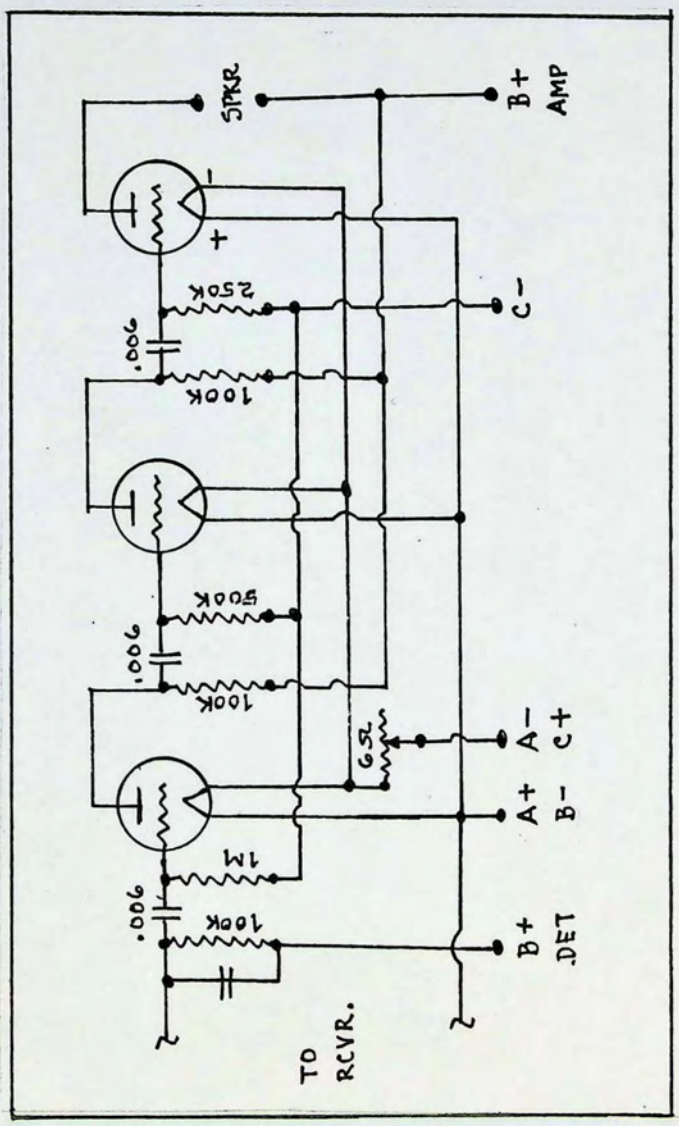
NOTE: Applicable to 2-stage xfrmr.-cpld. circuits.

TYPICAL R-C STAGE:

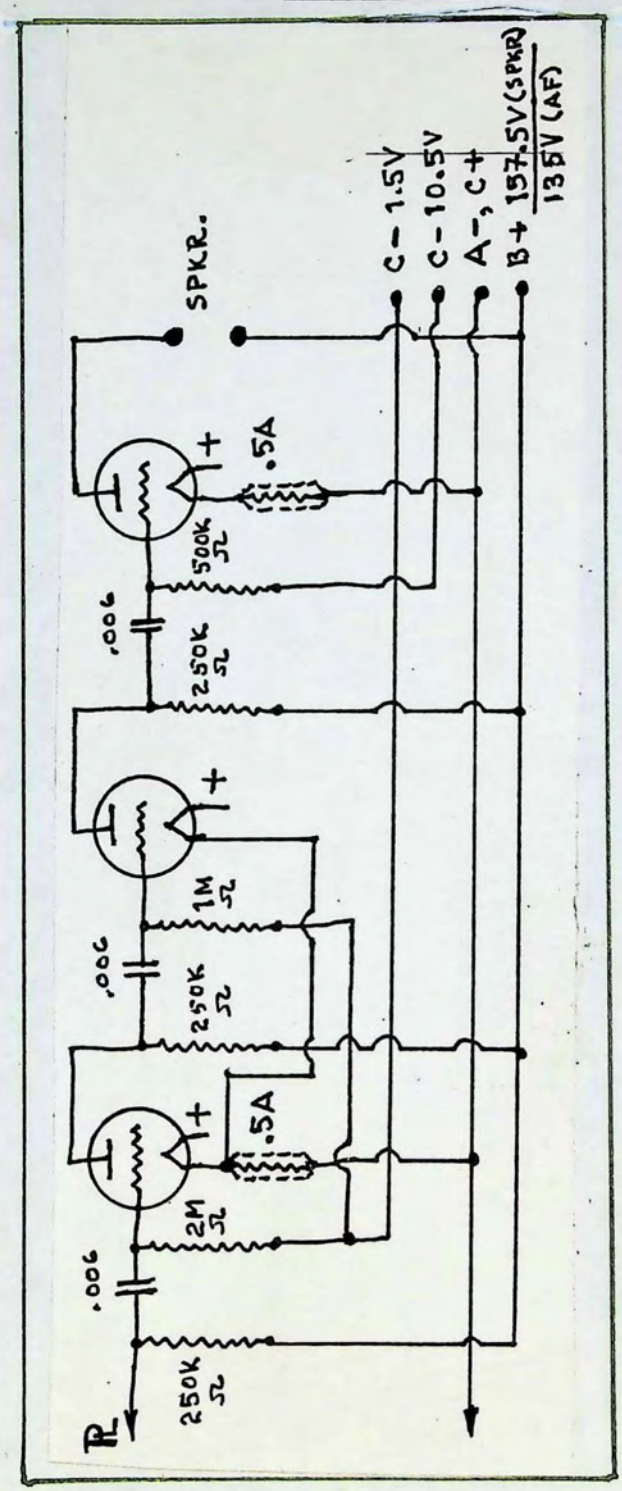



Either resistor may be replaced w/ an AF choke to obtain impedance, but little will be gained.

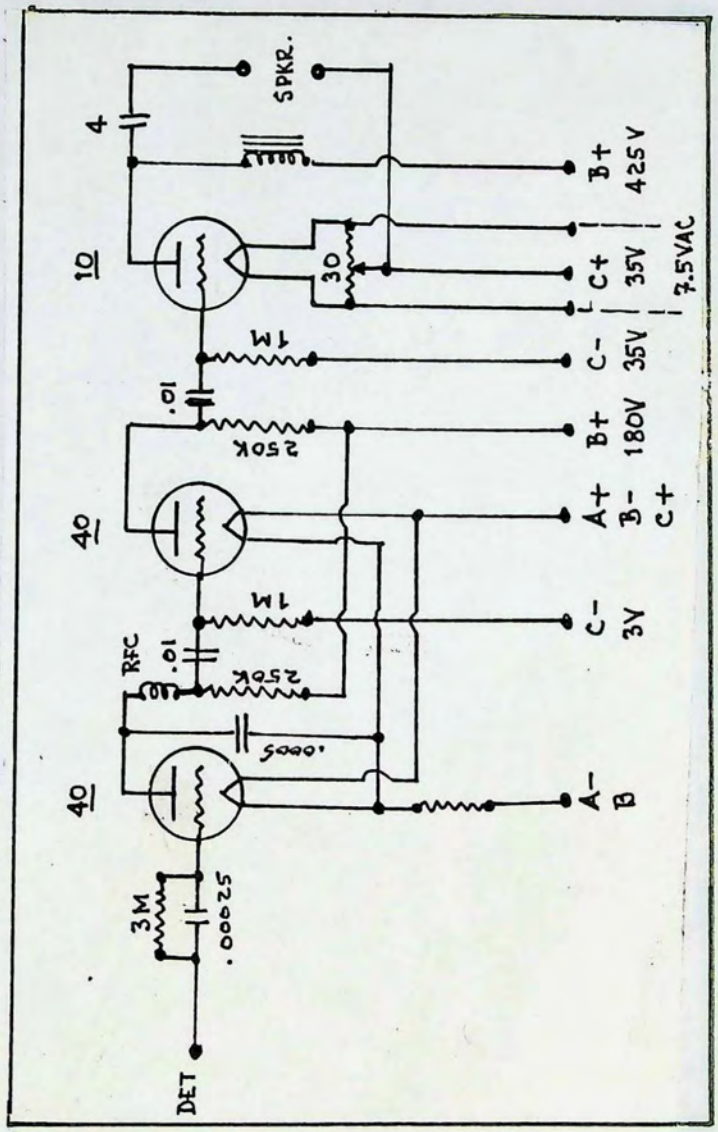
1927 R-C AMPLIFIER, Sht. 1



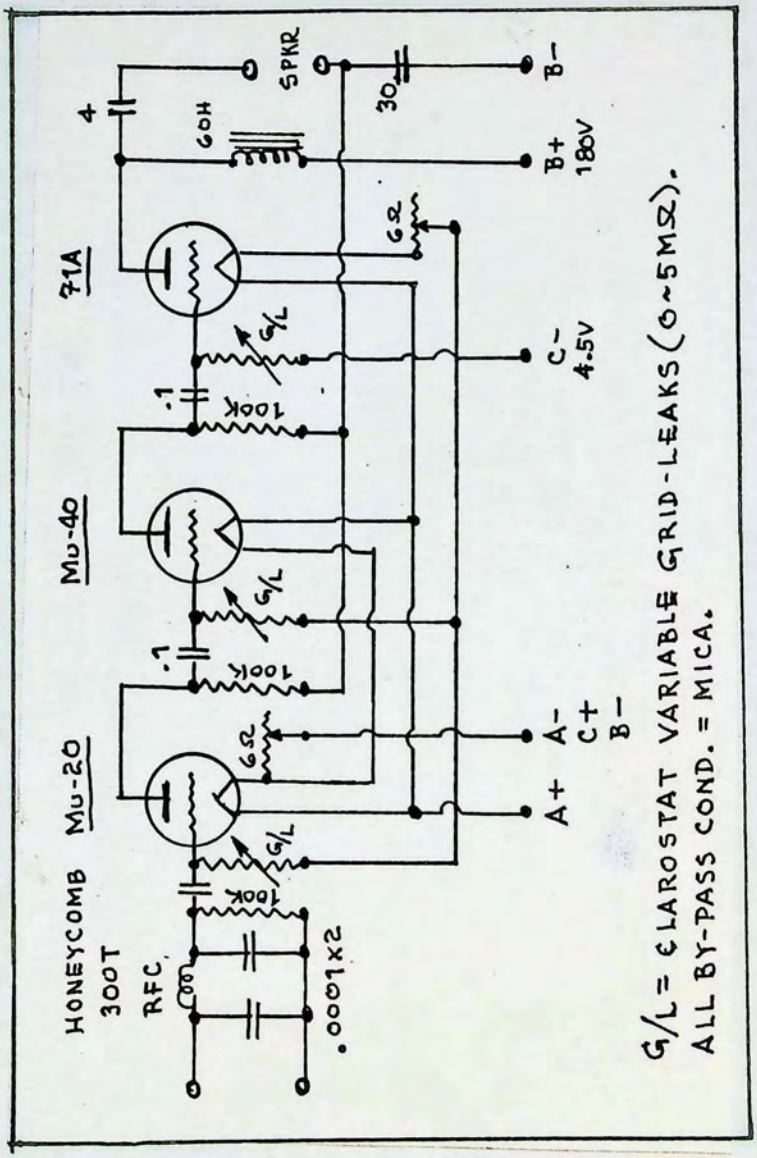
1927 R-C AMPLIFIER, Sht. 2



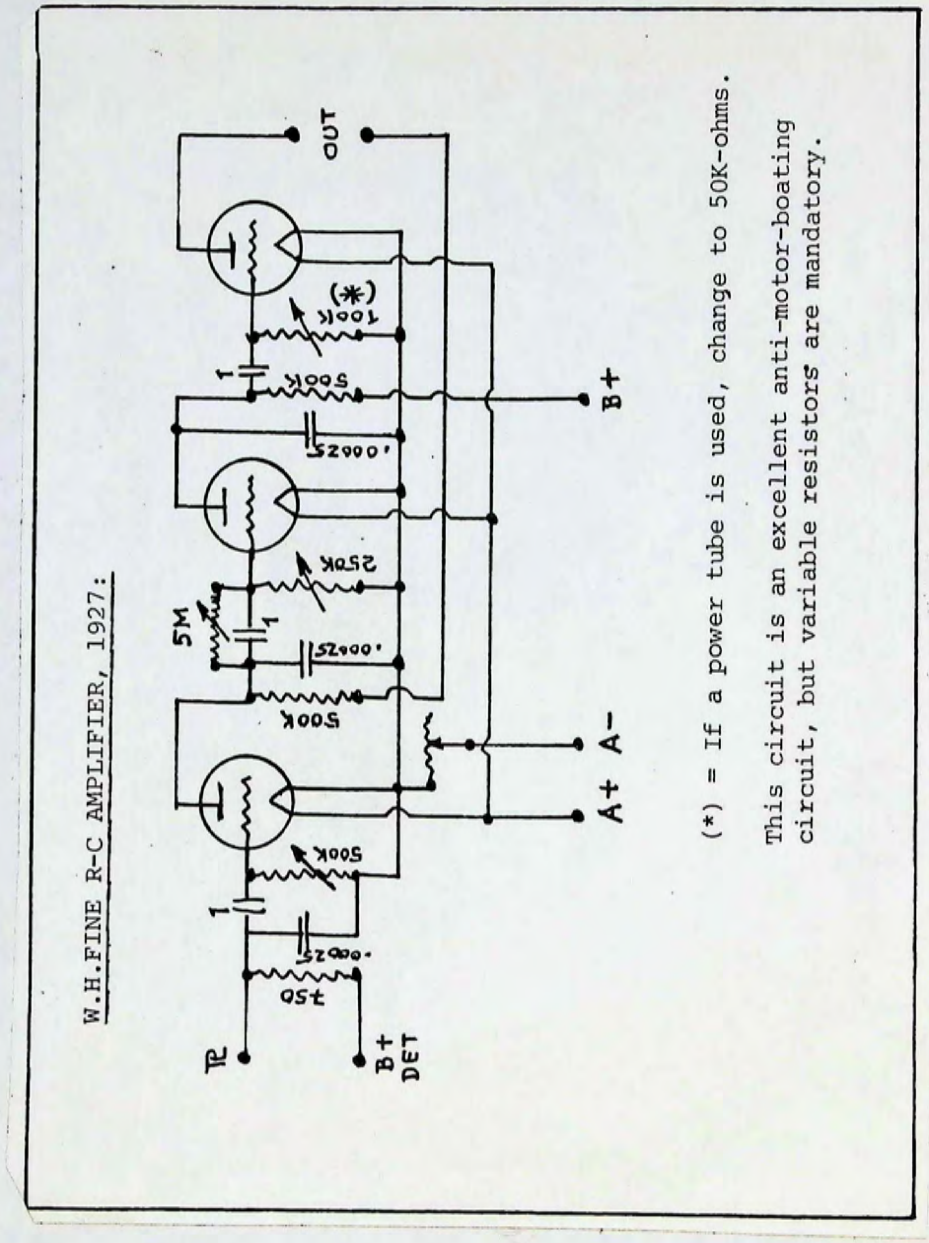
1928 R-C AMPLIFIER, Sht. 1



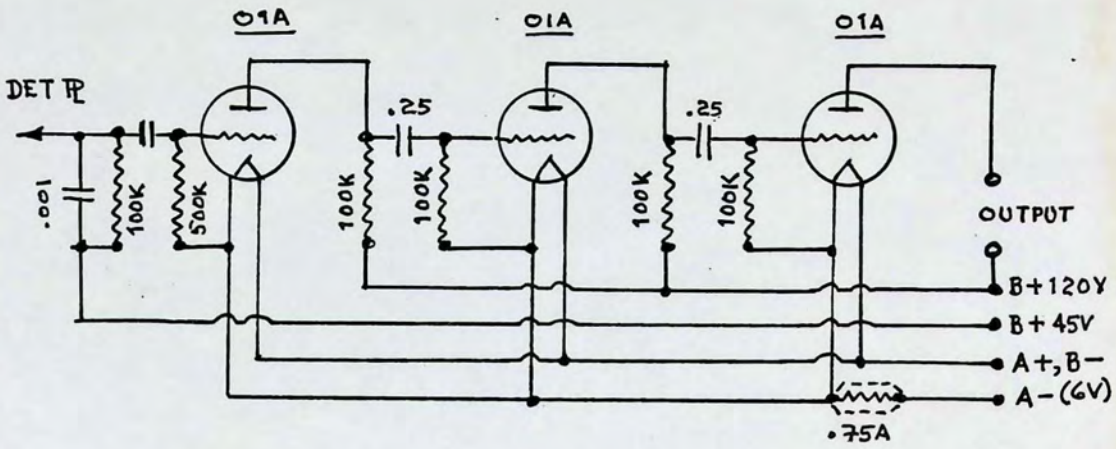
1928 R-C AMPLIFIER, Sht. 2

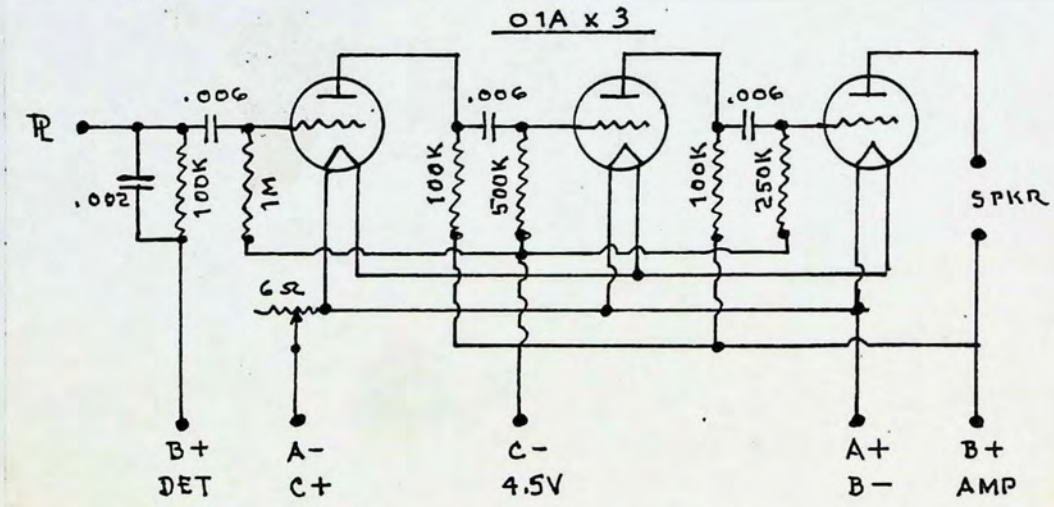


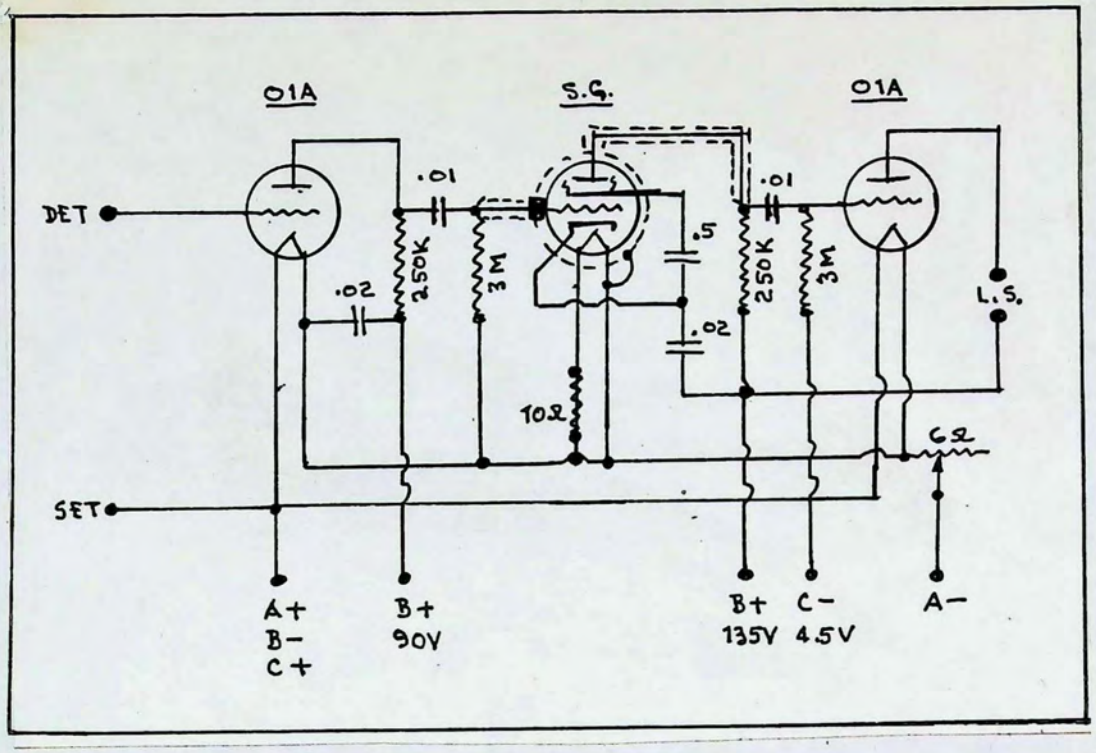
TYPICAL TWO TUBE R-C AMPLIFIERS #1



TYPICAL 3-STAGE R-C AMPLIFIERS




01A
S.G.
01A
DET
.01
.02
250K
3M
.5
.02
.01
250K
3M
L.S.
10Ω
G Ω
SET
A+
B-
C+
B+
90V
B+
135V
C-
4.5V
A-

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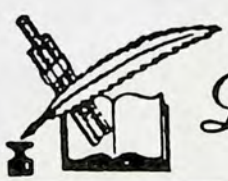

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